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(54) **CONDENSING APPARATUS**

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See application file for complete search history.

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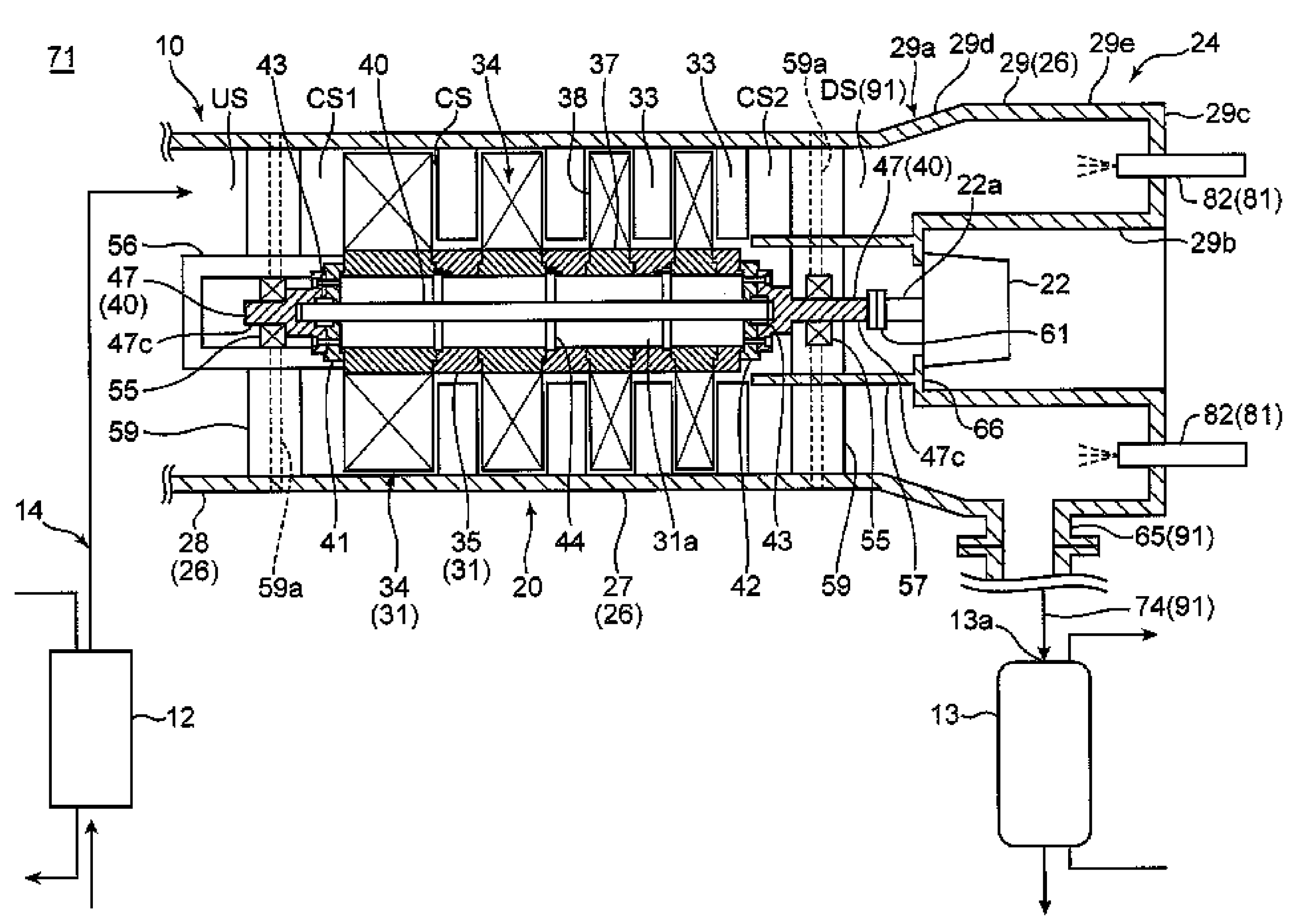
(57) **ABSTRACT**

The condensing apparatus **71** includes: a compressor **10** which has a compression part **20** compressing a working fluid; a condenser **13** which condenses the working fluid
(Continued)



compressed by the compression part **20**; and a spray mechanism **81** including a nozzle **82** which sprays a cooling fluid into a fluid passage **91** to cool the working fluid flowing through the fluid passage **91** between a discharge opening CS**2** of the compression part **20** and an inlet **13***a* of the condenser **13**.

8 Claims, 5 Drawing Sheets

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F28B 9/04	(2006.01)
F28B 3/04	(2006.01)
F28B 5/00	(2006.01)
F25B 40/04	(2006.01)
F25B 9/00	(2006.01)

(52) **U.S. Cl.**

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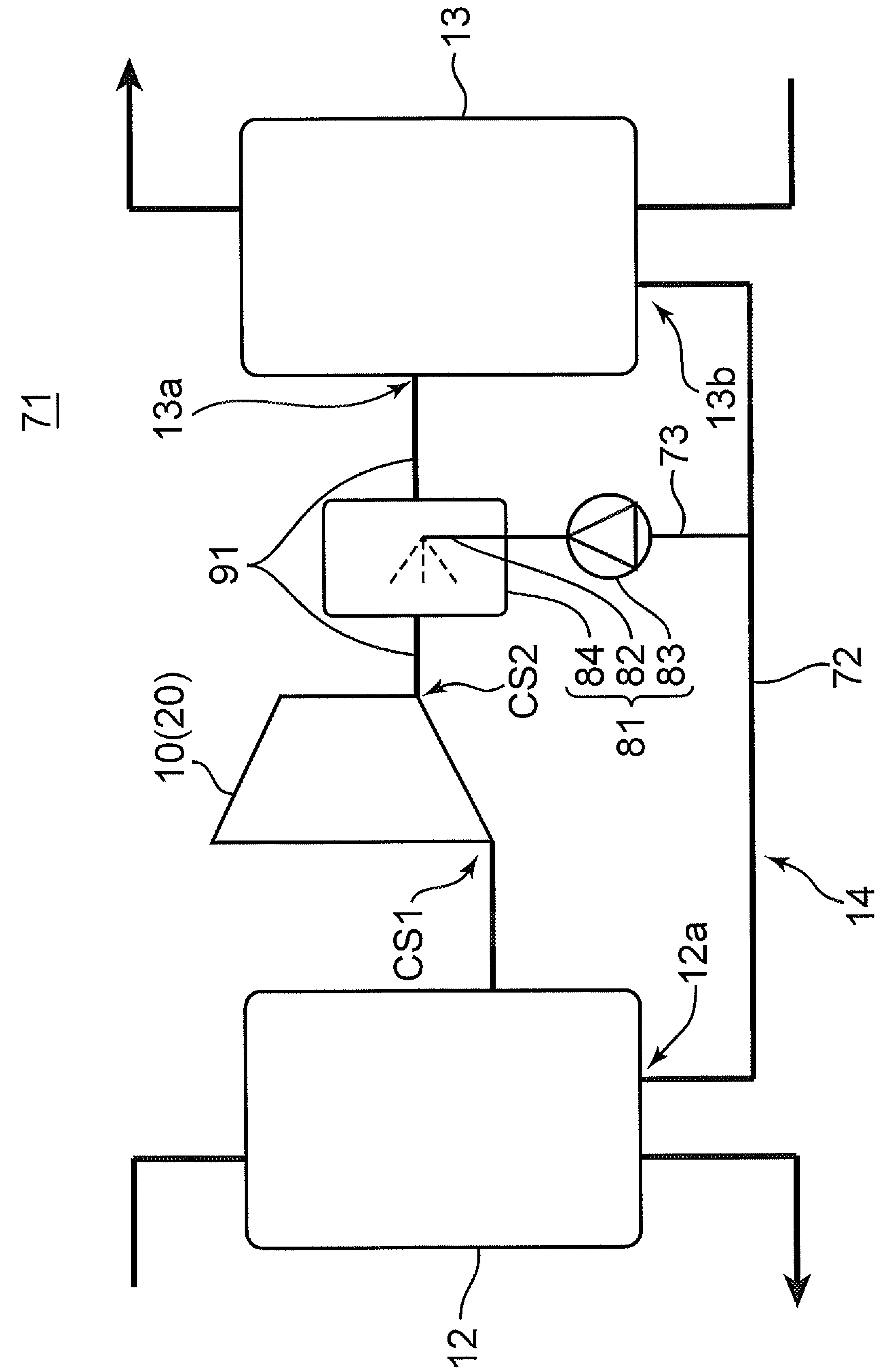
FIG. 1



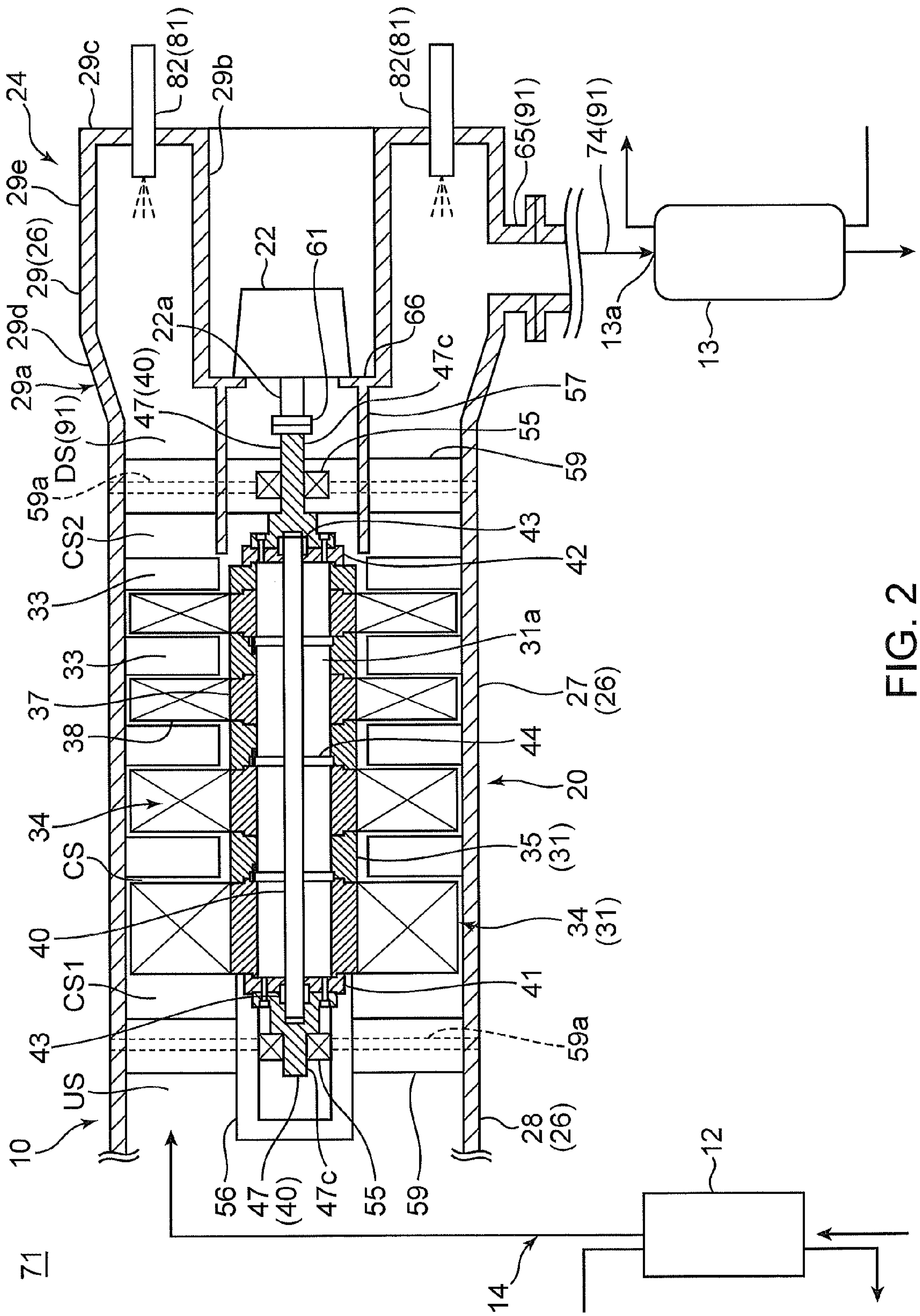

24
29c
82(81)
29b
82(81)
65(91)
74(91)
29e
29(26)
29d
29a
22
61
22a
66
47c
47(40)
DS(91)
57
55
59
59a
CS2
43
42
33
31a
33
37
27
(26)
38
44
34
20
CS
35
(31)
40
34
(31)
CS1
41
43
59a
US
10
28
(26)
56
47
(40)
47c
55
59
12
13a
13
14
71

FIG. 2

FIG. 3

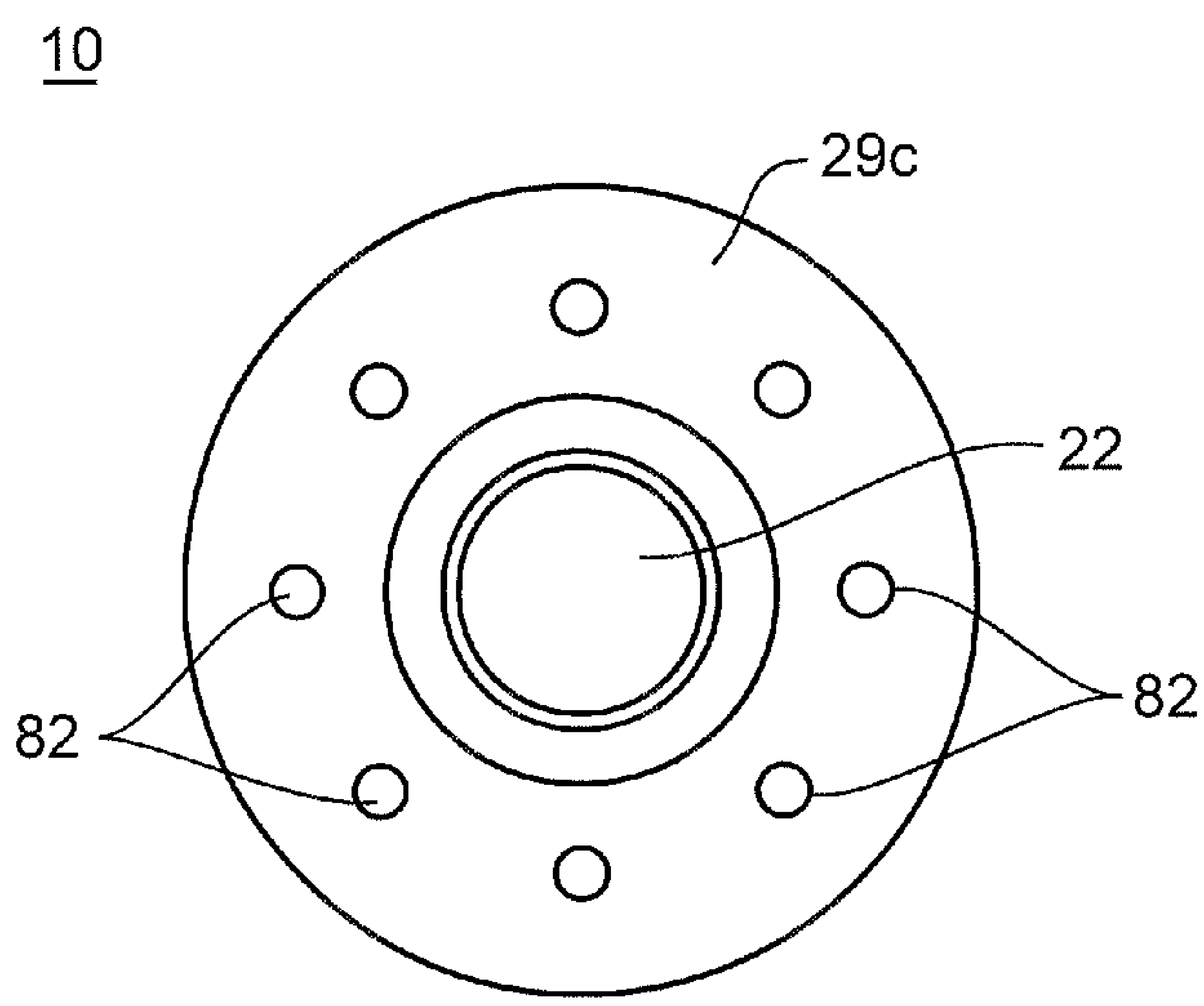


FIG. 4

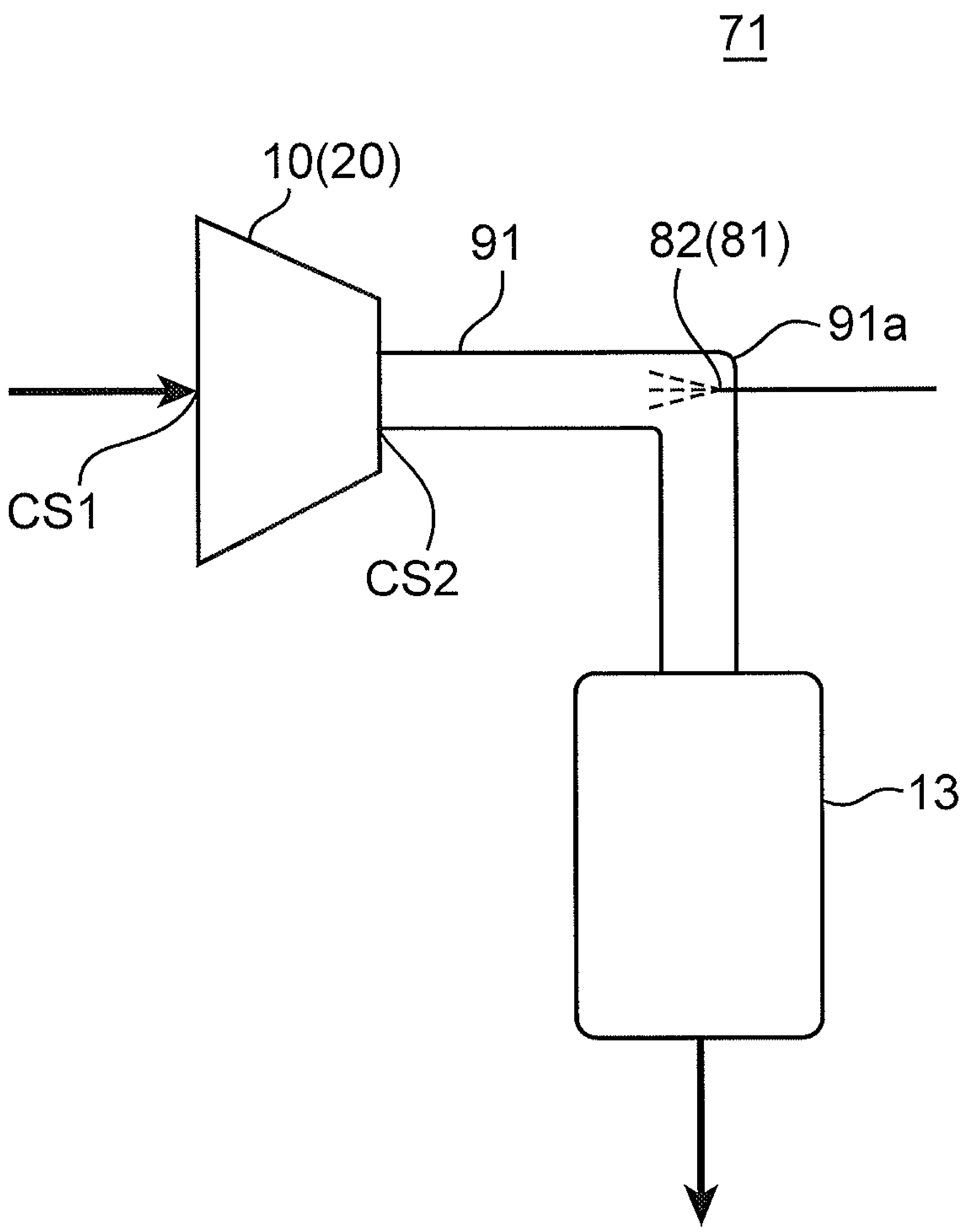


FIG. 5A

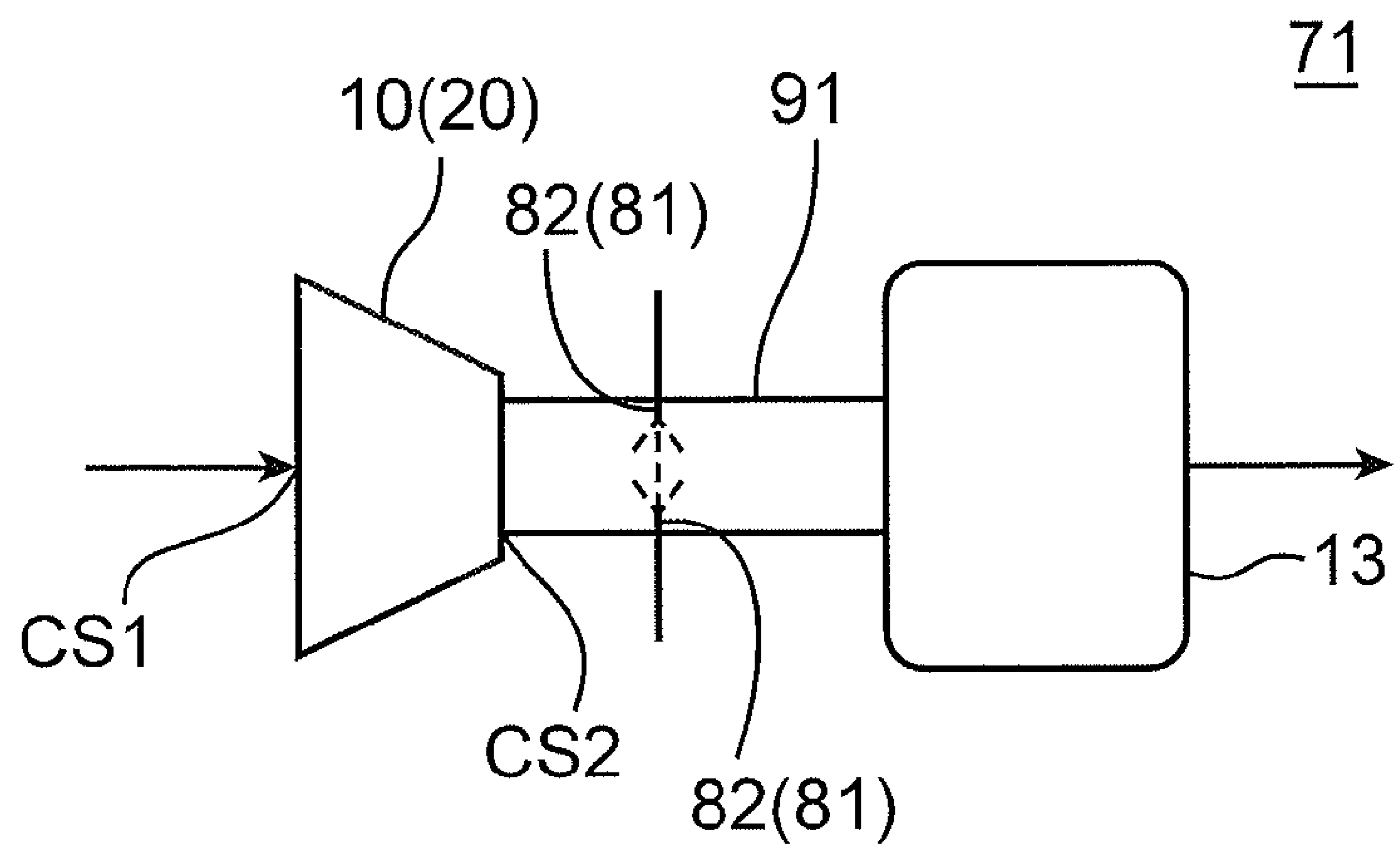
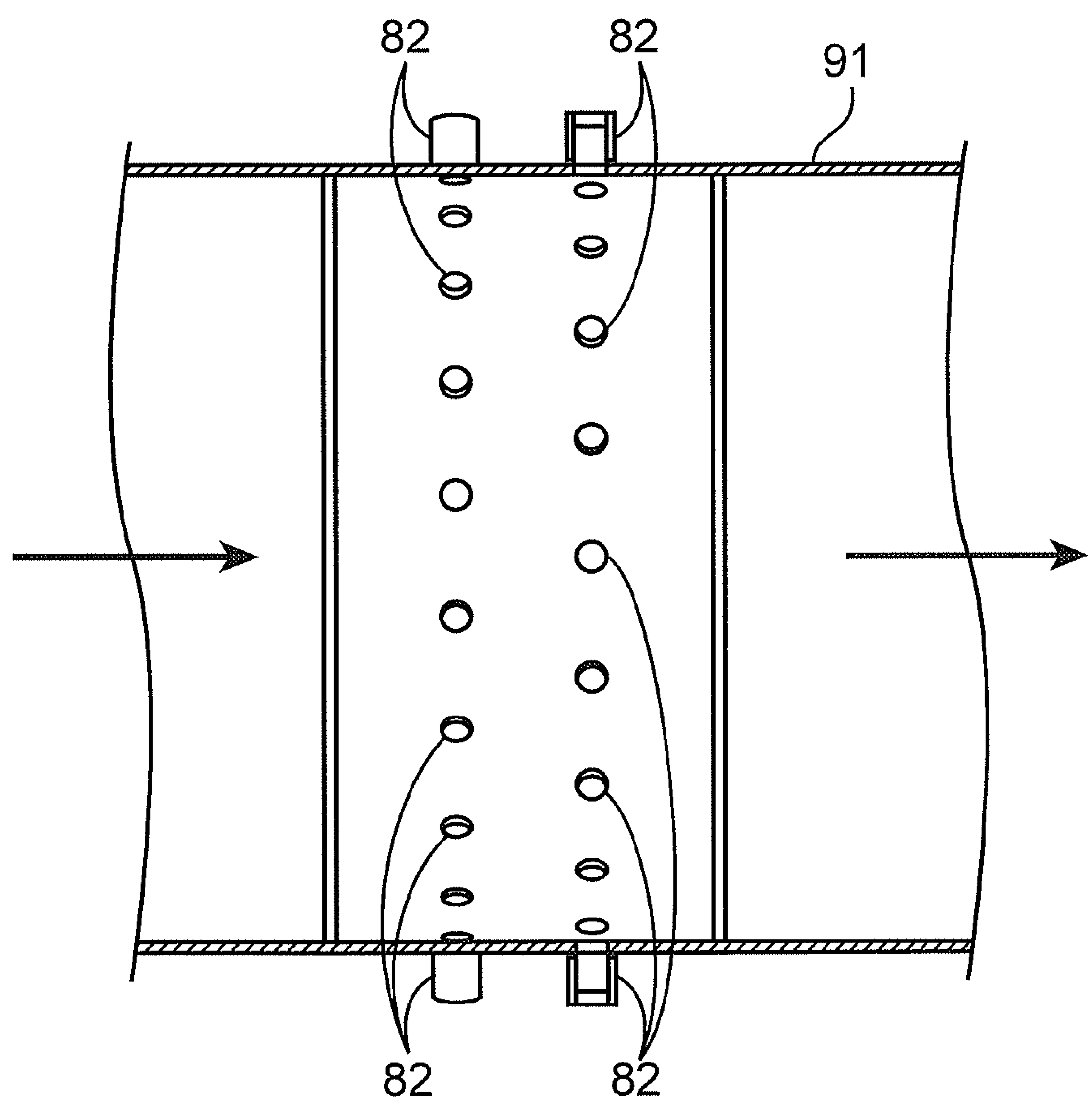


FIG. 5B



CONDENSING APPARATUS

TECHNICAL FIELD

The present invention relates to a condensing apparatus used for such as refrigerator.

BACKGROUND ART

Conventionally, a refrigerator provided with a refrigerant circuit is known, and as a working fluid (refrigerant) for the refrigerator, for example, various fluids are used such as water and a hydrocarbon process gas.

In the refrigerator, the refrigerant evaporated by an evaporator is compressed by a compressor and turns to superheated vapor, and then, the superheated vapor is condensed by a condenser. In the condenser, the superheated vapor is cooled, for example, with cooling water and turns to saturated vapor, and then, the saturated vapor is further cooled and condensed. Hence, the condenser has two main heat-transfer regions: a superheat region where the superheated vapor turns to the saturated vapor and a condensation region where the saturated vapor is condensed. For example, Patent Document 1 cited below discloses a refrigerator having a condensing apparatus in which water is used as a working fluid.

In the above superheat region, a heat-transfer coefficient is smaller than a heat-transfer coefficient in the condensation region. Hence, in the condenser, the area of a heat-transfer surface necessary for the superheat region tends to be larger, thereby requiring that the condenser should be enlarged.

Many refrigerators operate at a degree of superheat of approximately 5 to 7° C. However, in the refrigerator disclosed by Patent Document 1, for example, water is used as a refrigerant to make the degree of superheat higher, requiring a larger heat-transfer surface area in a superheat region. Specifically, in the refrigerator where water is used as the refrigerant, the vapor discharged from a compressor is superheated vapor having a large degree of superheat of approximately 100° C. The heat-transfer coefficient in the superheat region is approximately tens of watts/m^{2}K, which is approximately one-thousandth the heat-transfer coefficient (approximately 10000 W/m^{2}K) in a condensation region. Therefore, in the case where water is used as the refrigerant, the quantity of heat transferred in the superheat region is only several percent of the quantity of heat transferred in the whole of a condenser. Despite this fact, the superheat region needs a heat-transfer surface area equivalent to that of the condensation region, and thereby, the condenser especially tends to be large.

CITATION LIST

Patent Document

Patent Document 1: Japanese Unexamined Patent Publication No. 2003-534519A

SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide a condensing apparatus in which a condenser can be miniaturized.

A condensing apparatus according to the present invention includes a compressor which has a compression part compressing a working fluid; a condenser which condenses the working fluid compressed by the compression part; and a spray mechanism having a nozzle which sprays a cooling fluid into a fluid passage to cool the working fluid flowing through the fluid passage between a discharge opening of the compression part and an inlet of the condenser.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view showing a configuration of a condensing apparatus according to a first embodiment of the present invention.

FIG. **2** is a schematic view showing a configuration of a condensing apparatus according to a second embodiment of the present invention, mainly showing a specific configuration of a compressor in the condensing apparatus.

FIG. **3** is an end view of the compressor of FIG. **2**, seen from the downstream side in the axial direction thereof.

FIG. **4** is a schematic view showing a variation **1** of the condensing apparatus.

FIG. **5**A is a schematic view showing a variation **2** of the condensing apparatus and FIG. **5**B is an enlarged sectional view showing a part of piping connecting a compressor and a condenser in a variation **3** of the condensing apparatus.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

Embodiments of the present invention will be below described in detail with reference to the drawings.

<First Embodiment>

As shown in FIG. **1**, a condensing apparatus **71** according to this embodiment includes: a refrigerant circuit **14** provided with a compressor **10**, an evaporator **12** and a condenser **13**; and a spray mechanism **81**. The condensing apparatus **71** can be used for such as a refrigerator.

The compressor **10** houses a compression part **20** including, for example, a rotor (not shown) and rotating the rotor to thereby compress water vapor as a working fluid (refrigerant) evaporated by the evaporator **12**. The temperature and pressure of the water vapor are relatively low, and in this embodiment, the water vapor as the working fluid compressed by the compression part **20** has, for example, a temperature of 200° C. or below at atmospheric pressure or below at a discharge opening CS**2** of the compression part **20**.

Specifically, for example, at a suction opening CS**1** of the compression part **20**, the water vapor as the working fluid has a pressure of approximately 0.8 to 1.7 kPa and a temperature of approximately 5 to 15° C. At the discharge opening CS**2** of the compression part **20**, it has a pressure of approximately 1.5 to 8 kPa and a temperature of approximately 40 to 200° C.

The condenser **13** has a structure designed to keep the working fluid from coming into direct contact with a fluid (e.g., cooling water or the like) for condensing the working fluid, and hence, it is an indirect heat exchanger having divided spaces for permitting those fluids to flow separately.

The indirect heat exchanger makes a heat exchange indirectly between the working fluid and the fluid for condensing the working fluid, for example, via a heat-transfer tube, a partition wall or the like. The pressure range and the temperature range inside of the condenser **13** and the pressure range and the temperature range inside of a fluid passage **91** (described later) are substantially equal to the pressure range and the temperature range in the above discharge opening CS**2** of the compression part **20**.

Through the refrigerant circuit **14**, the working fluid compressed by the compressor **10** is sent to the condenser and condensed there. In this way, the working fluid undergoes phase changes and circulates through the refrigerant circuit **14**. The evaporator **12** evaporates the refrigerant and thereby supplies a secondary heating medium with cold heat, and the secondary heating medium is supplied to a user unit (not shown) cooling an object to be cooled such as room air.

The spray mechanism **81** sprays a cooling fluid into the fluid passage **91** between the discharge opening CS**2** of the compression part **20** and an inlet **13***a* of the condenser **13** and thereby cools the working fluid flowing through the fluid passage **91**. The spray mechanism **81** includes a nozzle **82**, a pump **83** and a spray chamber **84**.

The spray chamber **84** is arranged in the middle of the fluid passage **91** between the discharge opening CS**2** of the compression part **20** and the inlet **13***a* of the condenser **13**.

The nozzle **82** is arranged inside of the spray chamber **84** and the pump **83** is arranged in the middle of a branch pipe **73** which branches from piping **72** connecting an outlet **13***b* of the condenser **13** and an inlet **12***a* of the evaporator **12**.

The nozzle **82** is connected to the front end of the branch pipe **73**.

The working fluid condensed by the condenser **13** and discharged from the outlet **13***b* flows through the piping **72** toward the evaporator **12**. At this time, if the pump **83** is in operation, then a part of the working fluid flowing through the piping **72** is sent to the nozzle **82** through the branch pipe **73** and is sprayed as the cooling fluid from the nozzle **82**. Hence, in the first embodiment, the part of the working fluid sent to the nozzle **82** through the branch pipe **73** is used as the cooling fluid. The nozzle **82** is designed to spray the working fluid as the cooling fluid toward the upstream side of the fluid passage **91**.

<Second Embodiment>

FIG. **2** is a schematic view showing a configuration of a condensing apparatus **71** according to a second embodiment of the present invention, mainly showing a specific configuration of the compressor **10**. The condensing apparatus according to the second embodiment differs from that according to the first embodiment in the respect that the nozzle **82** of the spray mechanism **81** is attached directly to the compressor **10**. The compressor **10** is configured as an axial compressor. The condensing apparatus **71** can be used for such as a refrigerator.

As shown in FIG. **2**, the compressor **10** includes the compression part **20** having a compression space CS for compressing a working fluid, an electric motor **22** driving the compression part **20**, and a velocity reducing part **24** reducing the flow velocity of the working fluid discharged from the compression space CS. The compressor **10** includes a casing **26** formed by: a first case portion **27** arranged in the compression part **20** and having a cylindrical shape; a second case portion **28** arranged on the one end side (upstream side) of the compression part **20**; and a third case portion **29** arranged in the velocity reducing part **24** on the other end side (downstream side) of the compression part **20**.

The compression part **20** includes the first case portion **27** and a rotor **31** inside of the first case portion **27**. The space between the first case portion **27** and the rotor **31** functions as the compression space CS for compressing the working fluid. The compression space CS includes the suction opening CS**1** on the left and the discharge opening CS**2** on the right of FIG. **2**. Through the suction opening CS**1** on the left, the working fluid evaporated by the evaporator **12** is sucked into the compression space CS, compressed there as it goes to the right and discharged from the discharge opening CS**2**.

On the inner circumferential surface of the first case portion **27**, a plurality of stationary vanes **33** are fixed apart from each other in the axial direction. The first case portion **27** is set in such a way that the axial direction is horizontal.

The rotor **31** includes a plurality of rotor vanes **34** apart from each other in the axial direction and alternate with the stationary vanes **33**, and a plurality of spacers **35**. Each spacer **35** is a cylindrical member and arranged inside in the radial direction of the corresponding stationary vane **33** and between the corresponding adjacent rotor vanes **34**.

FIG. **2** shows the four rotor vanes **34** and the four spacers **35**, but the present invention is not limited to this configuration.

The rotor vane **34** includes a cylindrical boss portion **37** and a vane portion **38** around and united with the boss portion **37**. A plurality of the vane portions **38** are provided in the peripheral direction of the boss portion **37**. The boss portion **37** has an outer circumferential surface flush with an outer circumferential surface of the spacer **35**, and has an inner circumferential surface flush with an inner circumferential surface of the spacer **35**.

The compression part **20** includes a driving shaft **40**, a first pressing member **41**, a second pressing member **42**, a nut **43**, and a disk member **44**.

The driving shaft **40** is on the axial center of the first case portion **27** and extends in the axial direction of the first case portion **27**. Both end portions **47** and **47** of the driving shaft **40** are outside of the rotor vanes **34** and the spacers **35** in the axial direction.

The first pressing member **41** is arranged in contact with the most upstream rotor vane **34** while the second pressing member **42** is arranged in contact with the spacer **35** outside of the most downstream rotor vane **34**. The first and second pressing members **41** and **42** are arranged opposite in the axial direction, even though having the same configuration.

The first pressing member **41** has a disk shape and the pressing members **41** and **42** are each formed with a central through hole for inserting the driving shaft **40**. The first pressing member **41** is fitted to the rotor vane **34**, and thereby, the axial center of the first pressing member **41** coincides with the axial center of the most upstream rotor vane **34**.

The second pressing member **42** is fitted to the spacer **35** outside of the most downstream rotor vane **34**, and thereby, the axial center of the second pressing member **42** coincides with the axial center of the most downstream spacer **35**. The rotor vanes **34** are each fitted to the spacers **35** adjacent thereto.

The spacer **35** and the boss portion **37** have an inner diameter far larger than the outer diameter of the driving shaft **40**. Between the cylindrical part formed by the connected spacer **35** and boss portion **37** and the driving shaft **40**, therefore, a space extending in the axial direction is formed, and the disk member **44** is provided in this space or an inner space **31***a* of the rotor **31**.

The disk member **44** is perpendicularly postured to the driving shaft **40** and formed at the center with a through hole penetrating in the thickness direction. The driving shaft **40** is inserted in the through hole and thereby supported with each disk member **44** at a plurality of places in the middle thereof.

As shown in FIG. **2**, the both end portions **47** and **47** of the driving shaft **40** are each supported with bearings **55** and **55** corresponding thereto in such a way that the both end portions **47** and **47** are rotatable.

Both bearings **55** and **55** are placed in an upstream housing **56** at one end and a downstream housing **57** at the other end, respectively. The upstream housing **56** and the second case portion **28** form a cylindrical space between and this space becomes an upstream space US for flowing the working fluid led into the compression space CS. On the other hand, the downstream housing **57** and the third case portion **29** form a cylindrical space between and this space becomes a downstream space DS for flowing the working fluid led from the compression space CS.

The housings **56** and **57** are supported to the second case portion **28** and the third case portion **29** respectively via a plurality of support members **59**, **59** each having a rod shape and arranged radially in the circumferential directions. Each support member **59**, **59** has a streamline shape in section and thereby does not block a flow of the working fluid even in the upstream space US and the downstream space DS. The figure shows an example where the support member **59** comes into the housing **57** in the downstream space DS, but this part coming into the housing **57** not necessarily has a rod shape.

The support member **59** is formed with supply-and-discharge passages **59***a* for supplying and discharging a lubricant. The lubricant is introduced from outside of the second case portion **28** and the third case portion **29**, fed through one supply-and-discharge passage **59***a* to the bearing **55** and discharged through the other supply-and-discharge passage **59***a* from the bearing **55**.

The end portion **47** of the driving shaft **40** on the discharge opening CS**2** side is inside of the downstream housing **57** and connected to a rotating shaft **22***a* of the electric motor **22** via a flexible coupling **61** as an example of a vibration damping part. The driving shaft **40** of the compression part **20** is connected without any speed-up gear to the rotating shaft **22***a* of the electric motor **22** and thereby the rotor **31** has the same rotational speed as that of the electric motor **22**.

The above described velocity reducing part **24** has the downstream space DS formed by the third case portion **29**. The third case portion **29** has an outer circumferential surface portion **29***a* connected to an end of the first case portion **27** in the axial direction, an inner circumferential surface portion **29***b* inward from the outer circumferential surface portion **29***a* and extending in the axial direction, an end surface portion **29***c* connecting ends of the outer circumferential surface portion **29***a* and the inner circumferential surface portion **29***b* in the axial directions.

The outer circumferential surface portion **29***a* is formed midway in the axial direction with a flare portion **29***d* which is cylindrical and whose inner diameter gradually enlarges as it goes away from the discharge opening CS**2**. It is also formed with a portion **29***e* having a fixed inner diameter ahead of the flare portion **29***d*. On the other hand, the inner circumferential surface portion **29***b* is connected to an end of the downstream housing **57** and shaped like a cylinder having a fixed outer diameter in the axial direction. Hence, the downstream space DS has: a taper part which has a ring shape in a perpendicular section to the axial direction and whose sectional area enlarges gradually; and a parallel part which has a ring shape in a perpendicular section to the axial direction and whose sectional area is unchanged.

At least the taper part functions as a diffuser which reduces the flow velocity of the working fluid compressed in the compression part **20** and thereby recovers the pressure thereof, while the parallel part functions as a collector collecting the fluid whose flow velocity has been reduced in the taper part. In the velocity reducing part **24**, the working fluid is sufficiently decelerated at the taper part and thereby recovers the pressure without an excessive loss at the parallel part. In the figure, the inner circumferential surface portion **29***b* is connected stepwise to the housing **57**, but it may be connected without any step. Further, the inner circumferential surface portion **29***b* may be tapered at a part thereof corresponding to the taper part of the outer circumferential surface portion **29***a*. Still further, the length or the like of the parallel part can be suitably selected in accordance with how much the flow velocity of the working fluid discharged from the discharge opening CS**2** should be reduced.

The outer circumferential surface portion **29***a* is formed at the portion **29***e* forming the parallel part with, an outlet port **65** connected to piping **74** for leading, to the condenser **13**, the working fluid whose flow velocity is reduced inside of the downstream space DS.

The inner circumferential surface portion **29***b* is formed with a motor support portion **66** extending inward in the radial direction from the connection part thereof to the housing **57**. The electric motor **22** is placed inward from the inner circumferential surface portion **29***b* of the velocity reducing part **24** and attached to the motor support portion **66**.

FIG. **3** is an end view of the compressor **10** of FIG. **2**, seen from the downstream side (the right side) in the axial direction thereof. As shown in FIGS. **2** and **3**, in the second embodiment, the spray mechanism **81** includes a plurality of the nozzles **82** and does not include a spray chamber separate from the compressor **10**, which is different from the first embodiment. As is not shown in FIG. **2**, the spray mechanism **81** is configured, in the same way as the first embodiment shown in FIG. **1**, in such a way that the pump **83** is arranged in the middle of the branch pipe **73** and the plurality of nozzles **82** are connected to the front end of the branch pipe **73**.

In the second embodiment, the fluid passage **91** between the discharge opening CS**2** of the compression part **20** and the inlet **13***a* of the condenser **13** includes the downstream space DS, the inner space of the outlet port **65** and the inner space of the piping **74**. The nozzles **82** are arranged in the downstream space DS of the fluid passage **91**.

The plurality of nozzles **82** are arranged in the end surface portion **29***c* of the third case portion **29**. The nozzles are placed at substantially regular intervals over substantially the full circumference of the ring-shaped space of the downstream space DS, thereby uniformly cooling the working fluid which is discharged from the discharge opening CS**2** of the compression part **20** and flows through the ring-shaped space.

Each nozzle **82** is inserted into the downstream space DS from a through hole (not shown) formed in the end surface portion **29***c* in such away that a spray hole (not shown) formed at the tip of each nozzle **82** is inside of the downstream space DS. Each spray hole is oriented upward in the axial direction, thereby enabling each nozzle **82** to spray the working fluid with substantially facing toward the upstream side of the fluid passage **91**.

As shown in FIG. **2**, in the condensing apparatus **71**, the outlet port **65** is formed in the side part of the velocity reducing part **24** and extends substantially perpendicularly (downward in FIG. **2**) to the axial direction. The working fluid discharged from the discharge opening CS**2** of the compression part **20** flows in the axial direction inside of the velocity reducing part **24**, and thereafter, goes toward the outlet port **65**.

Here, the plurality of nozzles **82** are placed at the downstream end part (the end surface portion **29***c*) of the compressor **10** in the axial direction. In other words, the nozzles

82 are located downstream from the outlet port **65** in the velocity reducing part **24**. This makes it possible to prevent each nozzle **82** from obstructing a flow of the working fluid and thereby suppress a pressure loss thereof caused by the plurality of nozzles **82** provided there.

The nozzle **82** sprays the working fluid in the form of particles having certain sizes, and preferably, the particle sizes may be smaller to make a heat exchange more efficiently between the working fluids. In order to make the particle sizes smaller, the diameter of the spray hole (not shown) at the tip of the nozzle **82** needs to be narrowed, thereby naturally reducing the quantity of the working fluid sprayed by the nozzle **82**. Accordingly, in the second embodiment, the plurality of nozzles **82** are provided to thereby make the particle sizes of the sprayed working fluid smaller and simultaneously maintain the total quantity of the working fluid.

In the condensing apparatus **71** according to this embodiment, as the rotating shaft **22***a* of the electric motor **22** rotates in the compressor **10**, the driving shaft **40** of the compression part **20** also rotates at the same rotational speed to rotate the rotor **31** around the axis thereof. Thereby, the working fluid inside of the upstream space US is sucked through the suction opening CS**1** into the compression space CS, compressed and sent rightward in FIG. **2** in the compression space CS, discharged through the discharge opening CS**2** to the downstream space DS. The working fluid is decelerated and recovers the pressure in the velocity reducing part **24** and discharged through the outlet port **65**. The pump of the spray mechanism **81** comes into operation, thereby allowing the nozzle **82** to spray the working fluid as the cooling fluid into the space of the velocity reducing part **24** to cool the working fluid compressed by the compression part **20** in the space of the velocity reducing part **24**.

As described so far, in the first and second embodiments, the nozzle **82** sprays the working fluid as the cooling fluid into the fluid passage **91** to thereby cool the working fluid flowing through the fluid passage **91**. Therefore, the degree of superheat of the working fluid can be lowered in advance before the working fluid flows into the condenser **13**, thereby reducing the area of a heat-transfer surface necessary for cooling superheated vapor in the condenser **13** and hence miniaturizing the condenser. In addition, as described above, the heat-transfer surface area can be reduced, thereby cutting down costs for the condenser **13**.

Furthermore, in the first and second embodiments, the cooling fluid is sprayed toward the upstream side of the fluid passage **91**, thereby heightening the relative velocity of the cooling fluid to the working fluid, as compared with the case where the cooling fluid is sprayed toward the downstream side of the fluid passage **91** or sprayed perpendicularly to the fluid passage **91**. Therefore, the working fluid can exchange heat more efficiently with the cooling fluid to thereby more efficiently cool the working fluid flowing through the fluid passage **91**.

In the second embodiment, the flow velocity of the working fluid whose pressure and flow velocity have been raised in the compression part **20** can be reduced in the velocity reducing part **24** functioning as a diffuser. In addition, in the second embodiment, the nozzle **82** is attached to the compressor **10** in such a way that the cooling fluid can be sprayed into the space of the velocity reducing part **24**, and hence, there is no need to separately provide a member such as a spray chamber for spraying the cooling fluid from the nozzle **82**.

Moreover, in the second embodiment, the space of the velocity reducing part **24** extends in the axial direction of the rotating shaft of the electric motor **22** and surrounds the electric motor **22**, and the space has a ring shape in a perpendicular section to the axial direction. Further, the plurality of nozzles **82** are provided along the circumferential direction of the ring-shaped space. Therefore, the cooling fluid can be sprayed on a plurality of places inside of the space of the velocity reducing part **24**.

In the first and second embodiments, a part of the working fluid discharged from the outlet **13***b* the condenser **13** is used as the cooling fluid and the pump **83** sends the part of the working fluid to the nozzle **82**. According to this configuration, there is no need to prepare a cooling fluid separate from the working fluid.

In the second embodiment, the driving shaft of the compression part is connected without any speed-up gear to the rotating shaft of the electric motor. For example, in order to provide a speed-up gear for a conventional condensing apparatus used for a refrigerator, an electric motor needs to be offset (shifted in the radial direction thereof) with respect to a compression part. This offset is unnecessary for the condensing apparatus according to the second embodiment, and thereby, the width of the compressor in the diametrical direction can be prevented from enlarging. Further, no speed-up gear is provided, thereby preventing an increase in the width of the compressor in the diametrical direction.

The present invention is not limited to the above embodiments, and hence, various changes, modifications and the like can be expected without departing from the scope of the present invention. For example, the embodiments show the compressor **10** used for a condensing apparatus, but the present invention is not limited to this example. For example, the compressor **10** may be configured as a compressor used for, for example, a chiller for obtaining cooling water, an air conditioner, a concentrator or the like.

The working fluid is not limited to water vapor, and for example, a variety of fluids such as a hydrocarbon process gas can be used. Further, the compressor is not limited to an axial compressor.

Furthermore, in the above embodiments, as an example, the nozzle sprays the working fluid toward the upstream side of the fluid passage, but the present invention is not limited to this example. For example, the nozzle may spray the working fluid toward the downstream side of the fluid passage or sprayed perpendicularly to the fluid passage.

Moreover, for example, the present invention may be a condensing apparatus **71** according to a variation **1** shown in FIG. **4**. In the variation **1**, the fluid passage **91** is formed by piping connecting the compressor **10** and the condenser **13**. The piping has a bent part **91***a* for bending the direction in which the working fluid flows, and the nozzle **82** is arranged in the bent part **91***a*. When the working fluid flows through the bent part **91***a*, a pressure loss thereof is naturally caused more easily in the bent part **91***a* than in a straight part of the piping. Hence, the pressure loss is less affected, even though the nozzle is arranged in the bent part **91***a*.

Let's suppose that the nozzle is arranged in a straight part of the piping and sprays the cooling fluid toward the upstream side of the fluid passage. In this case, for example, the nozzle needs to be inserted into the piping from the side surface of the piping and be bent near the tip thereof in such a way that the spray hole of the nozzle faces toward the upstream side. This configuration can relatively enlarge the percentage of the nozzle occupied in the sectional area of the fluid passage, thereby making the pressure loss greater.

In contrast, as shown in FIG. **4**, if the nozzle **82** is arranged in the bent part **91***a*, then with the pressure loss being less affected by the arrangement thereof, the nozzle **82** is capable of spraying the cooling fluid toward the upstream side of the fluid passage.

As the case where the nozzle is arranged in a straight part of the piping, for example, FIG. **5**A shows a variation **2** where a plurality of the nozzles **82** are provided in a straight part of the fluid passage **91** (piping) connecting the compressor **10** and the condenser **13**. In the variation **2**, the two nozzles **82** face each other vertically in the straight part of the piping extending substantially horizontally. Specifically, the upper nozzle **82** has a spray hole (not shown) for spraying the cooling fluid downward inside of the piping (in a direction substantially perpendicular to a flow direction of the working fluid compressed by the compression part), while the lower nozzle **82** has a spray hole (not shown) for spraying the cooling fluid upward inside of the piping.

In addition, as seen in a variation **3** shown in FIG. **5**B, in a straight part of the fluid passage (piping) **91**, a plurality of (a large number of) the nozzles **82** may be provided in the shape of a ring along the circumferential direction of the piping. These nozzles **82** are arranged in the straight part and spray the cooling fluid in a direction substantially perpendicular to a flow direction of the working fluid compressed by the compression part. These nozzles **82** are placed at substantially regular intervals in the circumferential direction. In the variation **3**, two rows of the ring-shaped nozzles **82** are provided, and the two ring-shaped rows are separate from each other in the flow direction of the working fluid indicated by the arrows of FIG. **5**B. In the variation **3**, each nozzle **82** can spray the cooling fluid inward in the radial direction of the piping, thereby uniformly cooling the working fluid flowing through the piping.

Furthermore, in the variation **3**, each nozzle **82** is attached to the fluid passage (piping) **91** in such a way that the tip thereof hardly protrudes inward from the inner surface of the piping. Therefore, each nozzle **82** is prevented from obstructing a flow of the working fluid inside of the fluid passage **91**, and thereby, the pressure loss thereof is far less affected by the arrangement of the nozzles **82**.

In the variations **2** and **3**, the plurality of nozzles **82** are provided in the straight part of the fluid passage **91**, but a single nozzle **82** may be provided in the straight part. Moreover, the variations **2** and **3** show the examples where in the straight part of the fluid passage **91**, the nozzles **82** spray the cooling fluid inward in the radial direction thereof. However, the present invention is not limited to this, and for example, in the straight part of the fluid passage **91**, the nozzles **82** may spray the cooling fluid toward the upstream side thereof. In this case, for example, the nozzles **82** are inserted into the piping as the straight part of the fluid passage **91** and bent upstream near the tips of the nozzles **82** to thereby enable the nozzles **82** to spray the cooling fluid toward the upstream side.

Furthermore, for example, the nozzle may be directed diagonally to a flow direction of the working fluid in the straight part whereby the cooling fluid can be sprayed toward the upstream side. In this case, the nozzle is attached to the straight part of the piping in such a way that the tip thereof hardly protrudes inward from the inner surface of the piping. Therefore, the nozzle is prevented from obstructing a flow of the working fluid inside of the piping, and thereby, the pressure loss thereof is far less affected by the arrangement of the nozzle.

The above embodiment mainly includes inventions with the following configurations.

A condensing apparatus according to the present invention includes a compressor which has a compression part compressing a working fluid; a condenser which condenses the working fluid compressed by the compression part; and a spray mechanism having a nozzle which sprays a cooling fluid into a fluid passage to cool the working fluid flowing through the fluid passage between a discharge opening of the compression part and an inlet of the condenser.

In this aspect, the nozzle sprays the cooling fluid into the fluid passage to thereby cool the working fluid flowing through the fluid passage. Therefore, before the working fluid compressed by the compression part flows into the condenser, the degree of superheat of the working fluid can be lowered in advance. This makes it possible to reduce the area of a heat-transfer surface necessary for cooling superheated vapor in the condenser and thereby miniaturize the condenser. In addition, as described above, the heat-transfer surface area can be reduced, thereby cutting down costs for the condenser.

In the above condensing apparatus, it is preferable that the nozzle is arranged so as to spray the cooling fluid toward an upstream side of the fluid passage.

In this aspect, the cooling fluid is sprayed toward the upstream side of the fluid passage, thereby heightening the relative velocity of the cooling fluid to the working fluid, as compared with the case where the cooling fluid is sprayed toward the downstream side of the fluid passage or sprayed perpendicularly to the fluid passage. Therefore, the working fluid can exchange heat more efficiently with the cooling fluid to thereby more efficiently cool the working fluid flowing through the fluid passage and lower the degree of superheat thereof.

In the above condensing apparatus, the fluid passage may have a bent part adapted to bend a flow direction of the working fluid and the nozzle may be arranged in the bent part. When the working fluid flows through the bent part, a pressure loss thereof is naturally caused more easily in the bent part than in a straight part (e.g., straight piping) of the fluid passage. Hence, the pressure loss is less affected, even though the nozzle is arranged in the bent part.

In the above condensing apparatus, it is preferable that the condenser is an indirect heat exchanger which makes a heat exchange between the working fluid and a fluid for condensing the working fluid with both fluids being out of direct contact with each other.

For example, in a direct heat exchanger as a condenser where a working fluid is mixed with a fluid (e.g., cooling water) for condensing the working fluid, the cooling water comes into direct contact with the working fluid. Therefore, the area of a heat-transfer surface is relatively large, and hence, the above problem of the heat-transfer surface area in the superheat region tends to be relatively small.

On the other hand, in the indirect heat exchanger according to this aspect, the problem of the heat-transfer surface area in the superheat region becomes more serious than in the direct heat exchanger. Accordingly, the present invention is especially effective which is capable of spraying the cooling fluid into the fluid passage from the nozzle and thereby lowering the degree of superheat of the working fluid in advance before the working fluid flows into the condenser.

In the above condensing apparatus, it is preferable that: the compressor further includes a velocity reducing part having a space for reducing a flow velocity of the working fluid discharged from the discharge opening of the compression part; the space of the velocity reducing part forms a part of the fluid passage; and the nozzle sprays the cooling fluid on the working fluid flowing through the velocity reducing part.

In this aspect, the flow velocity of the working fluid whose pressure and flow velocity have been raised in the compression part can be reduced in the velocity reducing part functioning as a diffuser. In addition, the cooling fluid is sprayed into the space of the velocity reducing part, and hence, there is no need to separately provide a member such as a spray chamber for spraying the cooling fluid from the nozzle.

In the above condensing apparatus, it is preferable that: the compressor further includes an electric motor having a rotating shaft; the compression part has a driving shaft connected to the rotating shaft of the electric motor; the rotating shaft of the electric motor is connected to an end of the driving shaft on a side of the discharge opening; the space of the velocity reducing part is formed so as to extend in an axial direction of the rotating shaft of the electric motor and surround the electric motor, and has a ring shape in a perpendicular section to the axial direction; and a plurality of the nozzles are provided along a circumferential direction of the space having the ring shape.

In this aspect, a plurality of the nozzles are provided along the circumferential direction of the space having the ring shape. Therefore, the cooling fluid can be sprayed on a plurality of places inside of the space of the velocity reducing part to thereby further efficiently cool the working fluid flowing through the fluid passage and lower the degree of superheat thereof.

In the above condensing apparatus, it is preferable that: the compressor further includes an outlet port connected to the space of the velocity reducing part for discharging the working fluid whose flow velocity is reduced in the velocity reducing part; and the nozzle is arranged in the velocity reducing part and located downstream from the outlet port in the velocity reducing part.

In this aspect, the nozzle is located downstream from the outlet port in the velocity reducing part. This makes it possible to prevent the nozzle from obstructing a flow of the working fluid during a process of reducing the flow velocity in the velocity reducing part and thereby suppress a pressure loss thereof caused by the nozzle provided there.

In the above condensing apparatus, the fluid passage may have a straight part; and the nozzle may be arranged in the straight part and spray the cooling fluid in a direction substantially perpendicular to a flow direction of the working fluid.

In the above condensing apparatus, it is preferable that: the spray mechanism further includes a pump; the cooling fluid is a part of the working fluid which is condensed and discharged from an outlet of the condenser; and the pump sends the part of the working fluid to the nozzle.

In this aspect, a part of the working fluid discharged from the outlet of the condenser is used as the cooling fluid and the pump sends the part of the working fluid to the nozzle. According to this configuration, there is no need to prepare a cooling fluid separate from the working fluid.

In the above condensing apparatus, the present invention is especially suitable for the case where: the working fluid is water; and the pressure inside of the fluid passage through which the working fluid compressed by the compression part flows is within a range of 1.5 to 8 kPa.

In this aspect, the working fluid is water and the pressure inside of the fluid passage is extremely low. In this case, a heat exchange is apt to be made at a low efficiency in the condenser, thereby enlarging the area of a heat-transfer surface necessary for cooling superheated vapor to form saturated vapor in the condenser. Accordingly, in this aspect, the present invention is especially effective which is capable of spraying the cooling fluid into the fluid passage from the nozzle and thereby lowering the degree of superheat of the working fluid in advance before the working fluid flows into the condenser.

DESCRIPTION OF THE SYMBOLS

10: compressor
12: evaporator
13: condenser
14: refrigerant circuit
20: compression part
22: electric motor
22*a*: rotating shaft
24: velocity reducing part
31: rotor
40: driving shaft
71: condensing apparatus
81: spray mechanism
82: nozzle
83: pump
84: spray chamber
91: fluid passage
91*a*: bent part
CS**1**: compression-part suction opening
CS**2**: compression-part discharge opening

The invention claimed is:

1. A condensing apparatus, comprising:

a compressor which includes a compression part compressing a working fluid;

a condenser which condenses the working fluid compressed by the compression part; and

a spray mechanism including a nozzle which sprays a cooling fluid into a fluid passage to cool the working fluid flowing through the fluid passage between a discharge opening of the compression part and an inlet of the condenser,

wherein:

the compressor further includes an electric motor having a rotating shaft, and a velocity reducing part for reducing a flow velocity of the working fluid discharged from the discharge opening of the compression part, said velocity reducing part includes a case portion which has an outer circumferential surface portion and an inner circumferential surface portion, extending in an axial direction of the rotating shaft of the electric motor, and an end surface portion connecting downstream ends of the outer and the inner circumferential surface portions such that a space is formed in the case portion, said electrical motor in its entirety is disposed in a space formed radially inward from the inner circumferential surface portion;

the space of the velocity reducing part forms a part of the fluid passage; the space is formed so as to extend in the axial direction of the rotating shaft and has a ring shape in a perpendicular section to the axial direction; and

a plurality of the nozzles are arranged along a circumferential direction on the end surface portion having the ring shape and spray the cooling fluid on the working fluid flowing through the velocity reducing part.

2. The condensing apparatus according to claim **1**, wherein the nozzle is arranged so as to spray the cooling fluid toward an upstream side of the fluid passage.

3. The condensing apparatus according to claim **1**, wherein:

the fluid passage has a bent part adapted to bend a flow direction of the working fluid; and

the nozzle is arranged in the bent part.

4. The condensing apparatus according to claim **1**, wherein the condenser is an indirect heat exchanger which makes a heat exchange between the working fluid and a fluid for condensing the working fluid with both fluids being out of direct contact with each other.

5. The condensing apparatus according to claim **1**, wherein:

the compressor further includes an outlet port connected to the space of the velocity reducing part for discharging the working fluid whose flow velocity is reduced in the velocity reducing part; and

the nozzle is arranged in the velocity reducing part and located downstream from the outlet port in the velocity reducing part.

6. The condensing apparatus according to claim **1**, wherein:

the fluid passage has a straight part,

the nozzle is arranged in the straight part and sprays the cooling fluid in a direction substantially perpendicular to a flow direction of the working fluid.

7. The condensing apparatus according to claim **1**, wherein:

the spray mechanism further includes a pump;

the cooling fluid is a part of the working fluid which is condensed and discharged from an outlet of the condenser; and

the pump sends the part of the working fluid to the nozzle.

8. The condensing apparatus according to claim **1**, wherein:

the working fluid is water; and

a pressure inside of the fluid passage through which the working fluid compressed by the compression part flows is within a range of 1.5 to 8 kPa.

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